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ABSTRACT

This paper describes the background and development, provides an overview, and discusses the evaluation of the Carroll County, Maryland, elementary school science program emphasizing a hands-on approach to science. It uses locally developed materials designed at each grade level and focuses on process skills instead of concepts. The program development was guided by a statement of principles: (1) a hands-on approach and direct involvement of students; (2) concepts appropriate for the developmental level of students; and (3) extensive use of science processes. Instructional emphases are: (1) Grade 1--observation; (2) Grade 2--classification; (3) Grade 3--experimentation; (4) Grade 4--analysis; and (5) Grade 5--application. Materials needed for the program are supplied to teachers in custom-made kits developed for each grade level, designed and manufactured by Delta Education. Teachers receive trade books selected to match curriculum topics to supplement the curriculum. Summer enrichment materials have been prepared for each level. The lab-based approach was compared to two textbook based programs and found superior in amount of hands-on activity, inclusion of scientific processes, student motivation, and teacher motivation, but inferior for implementation. Subsequent reports include documentation of material development and curriculum guides for each grade level. (JM)

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THE CARROLL COUNTY ELEMENTARY SCIENCE PROGRAM A HANDS ON APPROACH

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CURRICULUM MATERIALS ARE AVAILABLE AS FOLLOWS:

Curriculum Guides - Grades 1 - 5
($10 each)
Summer Science Fun Package
($5 per set)

The Carroll County elementary science program is a newly implemented curriculum that emphasizes a hands-on approach to science. It is based upon locally developed materials that were designed at each grade level around science process skills instead of concepts. Successive grade levels are designed to employ both a greater number and a higher order of these processes. Since this is not a text program, all lessons are based upon hands-on activities contained in the teachers guide. Subsequent lessons are intended to extend these experiences into other areas such as art, language arts, or math where other applications can be made.

Carroll County is a rural school system consisting of approximately 20,000 students. There are sixteen elementary schools typically housing students in grades kindergarten through five. Three of the sixteen schools vary from that organizational pattern. Two are kindergarten through grade four and one is kindergarten through grade three. Two middle schools in the county also house either grade five or grades four and five. Schools in the system are both traditional, self-contained as well as open space facilities. Population distribution allows for students to attend the school in their neighborhood and follow a logical feeder school scheme from elementary to middle and high school.

The county continues to experience growth and an ever-changing student population, as youngsters move into the area from surrounding metropolitan school systems. Although the county typically does not rank highly in either per pupil expenditures or professional staffing ratios, it is consistently well above the state average in standarized test results.

PROJECT BACKGROUND

The initial planning for this project began in the summer of 1981. At that time, Concepts in Science had been in place in the Carroll County Public Schools for the previous thirteen years. Elementary teachers were surveyed and asked to 1) evaluate the curriculum in place and 2) identify any problems found in its use. Sixty-nine percent of the responding teachers indicated that the elementary science program needed to be either revised or replaced.

Based on these results, an Elementary Science Task Force consisting of teachers, principals, and supervisors was created in January 1982 to steer the revision process. They developed a "Statement of Principle" that philosophically described desirable characteristics of a program. Some of the key points in that statement were that elementary science should:

- be hands-on in nature with direct involvement of students.
- have concepts appropriate for the developmental level of students.
- make extensive utilization of the processes of science.

Over twenty textbook programs were rated using the key points of this "Statement of Principal." Twelve were judged to be worthy of further consideration. These were evaluated using the "Checklist for Evaluating Science Textbooks" developed at the University of Georgia which narrowed to three the number of commercial programs under consideration. The primary author of each of these met with the Task Force to present and discuss their series. Subsequently, a determination was made to pilot two of these along with a locally developed, laboratory-based approach to elementary science.

The decision to develop local materials was made since none of the commercial programs fully met all the criteria in the "Statement of Principle." The process used in the development of that program was different than that conventionally employed. Instead of basing the program upon a scope and sequence of content, the Task Force first determined what processes were to be taught at each grade level. Topics which lent themselves to those processes were then sought. After making certain there was no duplication between grade levels, writers developed lessons for each topic.

Needless to say, some of the lesson ideas used by the teacher writers were not of their own creation. Many of the ideas were patterned after other programs, especially those which placed heavy emphasis upon the science processes. However, what teachers were able to do was to write a program tailored for their own specific needs. More importantly, they set in motion a sequence of events that ultimately resulted in a tremendous amount of teacher commitment to the curriculum. The program was perceived as one developed by teachers to meet the needs of teachers. However, that view did not develop until after a pilot, expressions of teacher concerns, and subsequent revision.

OUR PROGRAM

One of the primary goals of this curriculum is for students to develop an understanding of science from a direct, hands-on approach. It emphasizes the development of the processes of science as a means of problem solving. Throughout the program what students learn is based upon these hands-on experiences, rather than just reading about science or memorizing a series of facts about science. The processes of observing, classification, measuring, recording, inferring and predicting are corner stones of the approach employed.

The development and sequencing of content in this program differs from what might be a more conventional approach. Instead of first determining what topics should be taught at each grade level, the Task Force initially determined which of the processes of science were appropriate with youngsters at the various levels. After these were sequenced, content topics were sought that best lent themselves to instruction utilizing those processes. Consideration was given to the development of the program in a manner that closely paralleled the "Maryland Curricular Framework".

As students progress from level to level, higher order processes are introduced. Instruction at each level is directed toward emphasizing the following skills:

Grade 1: Observation
Grade 2: Classification
Grade 3: Experimentation
Grade 4: Analysis
Grade 5: Application

The content of the curriculum consists of three basic units at each grade level. These units are essentially lesson clusters dealing with a topic of study and built around the science process skills identified for that grade level. Within the total program, a wide variety of topics in both the biological and physical sciences are included.

In first grade students work primarily on the skill of observation. There are three units of seeds, patterns and magnetism. To start the school year, students begin by collecting seeds. One of the methods used is for youngsters to place a white stocking on their feet and walk through fields of weeds and grasses. Using the seeds they collect as well as others brought in, students observe and classify them through a series of follow-up activities. Students learn the parts of the seed as well as other information about seeds.

Study in the first grade continues with a unit dealing with patterns. A large number of fruits such as the apple, orange, and kiwi are used so that students can readily observe the seed patterns present. Symmetry is introduced through utilization of certain letters of the alphabet and a select number of geometric shapes. The unit continues with the study of the patterns found in tracks. Besides the tracks made by animals, students investigate the ones produced by their own toys, especially small cars and trucks brought from home. Students might typically run them across a piece of carbon paper, leaving a track on the paper below.

The final first grade unit is that of magnetism. A large number of hands-on activities lead students to an understanding of magnetic and non-magnetic substances, magnetic poles, and magnetic lines of force. A particular emphasis is placed upon the idea that like poles repel and vice versa.

In second grade, the three units are those of insects, sink or float, and measurement which together emphasize the development of classification skills. Students construct sweep nets to collect insects, then bring their specimens back to the classroom where they are studied over a period of days. Youngsters also raise painted lady butterflies and the mealworms to view the stages in the life cycle of insects. In the sink or float unit, students construct boats from clay or aluminum in order to build one that will hold the greatest amount of cargo. To do this they must first undertake a series of investigations that provide ideas on how they may construct this device so that it will hold the most. In the measuring unit, students work with a series of simple activities dealing with measurement of mass, length, and time. This is closely related to work students do in their math classes. Among the activities undertaken by students are ones involving the construction and use of a simple balance and a water clock.

In third grade the skill focused upon is that of experimentation. Students undertake activities in three units: flight, measuring and plants. In the lessons on flight, students make an autogyro, parachute, and paper airplane to be used in a series of investigations which really focus upon the ideas of variables. Throughout this unit students are manipulating the placement of weights on these objects and determining how that affects the flight of each. Often this results in a third grade "fly off" in which students test their findings. Those youngsters who best understand the influence of the factors studied are able to produce the plane that flies the farthest or the parachute that lands the softest.

Third grade students continue with another unit on measurement. This builds upon what is done the previous year. Some of the activities undertaken deal with measurement related to bouncing balls. Youngsters investigate how altering the variables of the height from which a ball is dropped, the surface upon which it is dropped and the kind of ball itself affects how high a ball will bounce. Although this unit develops skills in the various aspects of measurement, the unstated focus continues to be that of variables and ways students can experiment in altering them.

Youngsters also study plants at this grade level. A sequence of lessons deal with seeds and the changes they undergo in the germination process. The seedlings that result are raised for a period of time in the classroom so their growth can be measured and charted. The influence of certain environmental conditions such as soil type is investigated. At the conclusion of the unit, students study the parts of the plant, especially the flower.

In fourth grade, students begin to focus upon the skill of analysis. The three basic units are bio-communities, electricity and chemistry. In animal communities students study pond water. Using microscopes, they observe the organisms present. This leads to a study of the role of the various organism and the interactions between them. A board game entitled "Food Chains of the Pond Community" has been developed to accompany this unit. This is followed by the study of the ant community where similar activities are undertaken.

In the electricity unit students undertake a sequence of investigations that begin with the study of static electricity. Students continue by learning about series and parallel circuits. For this a number of battery and bulb experiments are used. As a result of this, youngsters deal with the idea of a short circuit. Electromagnets, small motors, and buzzers are made and investigated. Many of these activities provide for a direct application to the everyday world.

Fourth grade students also study a unit on cupboard chemistry. Common household products are used to demonstrate the properties of matter in an exciting way. Student work results in an understanding of the states of matter, mixture and solutions, the dissolving process as well as acids and bases. The highlight of the unit is a fascinating "mystery goop" which has properties of both a solid and a liquid. Analysis skills are developed as students use observations they make about a series of known substances to identify the composition of unknown mixture of some of those materials.

The fifth grade curriculum consists of three units on earth science, soil analysis and small animals. In the first, youngsters undertake a large number of earth science activities which have a geology emphasis. Simple tests are applied to rocks and minerals, weathering, erosion, and sedimentation studied. The latter results in student work with fossils.

One of the small animals studied is the fruit fly. Students attempt to daily estimate the number of flies in a culture vial. Predictions of a continually increasing population eventually go awry and the culture declines as the food supply is exhausted.

The curriculum is supported and indeed defined by the curriculum guides at each grade level. These not only provide a sequence of basic lessons, but also include much of the teacher support materials that facilitate the implementation of the curriculum. Masters for transparencies, dittos, and other class handouts are included. Lessons specify the processes being taught, the content objectives and the estimated time required. Also, incorporated into each lesson are a series of structuring questions for possible use by the teacher. These assist the teacher in directing student thought toward the desired end.

While the basic lessons within each unit define the required content to be taught by all teachers, a series of extension activities provide a basis for enrichment, diversity and specialized interests. These activities are intended to follow-up the initial investigation. It is these extension activities that often carry the primary lessons into the areas of language arts, math, or art. For instance, students may write a story or draw pictures about what they have done. At the upper grade levels, students also maintain a journal in which they record what they have done and what they have found.

Many of the lessons and activities require the use of living organisms. This is particularly true in grade two where insects are studied and grade four when the pond community is investigated as a lead in to various protozoa, algae and other organisms. Also, grade five studies small animals including crayfish and fruit flies in a series of lessons.

Teachers are supplied these organisms through a system-level Live Materials Culture Center. While most of them are commercially available, several required sets of organisms are specific to this elementary science program. For instance, grade two uses a mealworm kit which consists of a specified proportion of larva, pupa and adult beetles. Fifth grade employs the fruit fly to study population dynamics and investigates the role food supply plays. For this, a special fruit fly kit is prepared which consists of ten cultures of the organisms started at specified time periods apart. Providing these living materials from within the system has helped ensure further implementation of the program by eliminating the inconvenience and financial considerations which could become impediments.

Science is typically taught either concurrently or alternately with a social studies unit in the elementary classroom. Depending on the grade level, 30 to 50 minutes per day are prescribed for science instruction three to four days per week. Teachers are finding that the lab-based, hands-on program requires a minimum of 30 minutes for set-up, lesson development, group activities, and clean-up.

Material needs for the program are supplied to teachers in custom made kits developed for each grade level. The intent has been to provide teachers with all supplies they need to implement the curriculum despite the fact that those same items might be readily available from other sources. As a result, things such as toothpicks, straws, sugar and other common items have been supplied to teachers as part of the kit. Although these could be obtained locally at grocery stores, hardware stores and the like, a determination was made that such a teacher inconvenience would negatively impact upon the extent to which people may be able to successfully and easily implement the program.

An agreement was made with Delta Education to design and custom make these kits. They took the lessons from each grade level and developed a list of required materials. A prototype kit for each grade level was built and provided for evaluation and modification by the writing team. Any additions, deletions, or other modifications were made with the intent of providing teachers with all materials required for the program. Accompanying each kit has been an itemized list of contents. Along with the current costs of each, this is provided to teachers yearly which simplifies their job in reordering materials.

Teachers also receive a series of trade books to supplement the curriclum at each grade level. The purpose of these is to provide additional reading and teacher support on the topics studied. Arrangements were made with Pulley Learning Associates in South Carolina to have a computerized match of the Carroll County lessons with the published materials currently on the market. From copies of the grade level curriculum guides provided them, Pulley Learning Associates generated a list of books for possible use with each topic and grade level. These were evaluated by teacher-writers as part of the selection process. Many were identified for classroom use with anywhere from one to ten copies provided to each teacher. Others were judged to be more appropriately housed in the library and were purchased through the schools' Media Center.

This elementary science program has been extended to a summer enrichment program. A package of materials entitled "Summer Science Fun" has been prepared for each grade level. The activities included serve as both reinforcement for the concepts taught during the school year and as enrichment by the introduction of new materials which go beyond that previously studied. Students who

undertake this and complete the package of activities on their own or with their parents help during the summer months have their efforts recognized with an appropriate certificate. Although this portion of the program is completely voluntary, over 44% of the youngsters have participated in the past.

The new program is one which compliments the rest of the total school program. It correlates highly with two system goals in the county of 1) ensuring that students develop critical lifetime thinking skills and 2) providing for active learning and reducing student non-poroductive, "down-time" in the classroom. The program thrust of utilizing scientific processes in instruction helps students learn how to learn. It helps to transfer logical and inductive thinking to other academic areas. Requiring that students take the role of the scientist in attacking scientific problems and actively utilizing processes ensures that active learning meaningful participation and application of learning occurs.

EVALUATION

The impact of this program was assessed by a year long study that compared it with two widely used text series: Concepts in Science and Addison-Wesley Science. The former was a conceptually based program while the latter was a program that provided a balance between concepts and processes. Forty teacher participants were randomly assigned to teach two of the three programs for one semester each. To avoid any potential bias, the number of teachers designated to use each program as their first assignment was the same as the number who taught it as their second.

This research was part of a pilot study with the results used to select one of the three programs included. Five basic research questions were used to evaluate the data. A statistical anaylsis indicated the following:

AMOUNT OF HANDS-ON ACTIVITY

Teachers reported that with the lab-based, non-textbook approach, more emphasis was placed on activities that provide for a direct hands-on approach. Unlike the text-based programs, this approach required that the lab activities be done to maintain integrity of the program. With the textbook programs, teachers were sometimes afforded the option of talking about, instead of actually doing, investigations.

INCLUSION OF SCIENTIFIC PROCESSES

Teachers reported the non-textbook approach provided for greater inclusion of the scientific processes and allowed for more discovery and experimentation on the part of students. Neither text program was as successful in providing activities where students gained new information rather than just confirmed material already know.

STUDENT MOTIVATION

Participating teachers perceived students to be more motivated by the non-textbook approach. Similarly, it more often caused them to go beyond the assigned activity and try ideas on their own. However, no differences were perceived in the way programs caused students to initiate questions that went beyond what had been presented.

An attitude survey was administered to all youngsters at both the beginning and the end of each semester. Student responses indicated they were more motivated by the non-text approach and the more concept oriented approach than the program studied which had more of a process and content balance.

Parents commented that youngsters came home talking about the non-text approach more frequently than either of the other two. Teacher perceptions class wanting to know "Are we going to do science today?" or "What are we going to do in science today?"

EASE OF PROGRAM IMPLEMENTATION

Participating teachers indicated the non-text approach would be much more difficult to implement. This resulted from the perception that it required more preparation time than either of the other two.

TEACHER MOTIVATION

Teachers indicated that they derived more satisfaction from the non-text approach. It also caused them to devote more time to teaching science. However, no program related differences were found in a 20-item questionnaire used to assess attitudes toward teaching science.

This study was undertaken as part of a pilot used in selecting a program to be implemented. Based upon these data, the Task Force selected the locally developed, laboratory-based program. However, much deliberation and turmoil went into the decision. It was evident that this program represented good science, which both involved and highly motivated youngsters. At the same time, the Task Force recognized reality; it was going to be very, very difficult to implement that program. After much agonizing, it was finally determined that the strengths of the lab based approach were characteristics of the program. The weaknesses of the other two were inherent of the programs themselves. Little could be done in terms of an implementation strategy or inservice training that could make those programs more hands-on in nature or motivating to both students and teachers.

PLANS FOR IMPROVEMENT

Problem areas related to the program consist of:

1) On-going staff development needs and support as well as training of new teachers.
2) Maintaining equipment and material needs--keeping the lab kits replenished and complete.
3) Avoiding teacher tendencies to move away from the intent of the program and teach an "easier," less actively involved program (reading about science and not doing it).

A recently awarded National Science Foundation (NSF) Honors Workshop grant is designed to ensure that exemplary science teachers in each school receive additional training and expertise in order to provide direction and support to science teachers in their schools. These honors-workshop participants were selected for their interest and enthusiasm in the science program as well as their credibility with fellow teachers. It is hoped that these inhouse teachers will serve as "coaches," providing companionship, support, technical knowledge, and feedback to their peers. They would also assist with the indoctrination and training of teachers new to the program and insure positive and productive initial experiences with the science curriculum. This is critical if the program is to continue to be successful.

Building principals, the honors workshop participants, and/or team leaders in each school must ensure that teachers are in fact using the program and that replacement materials are ordered in a timely fashion. The extent of replacement material needs is also an indicator of the degree to which the teacher is actually using the program and involving students in lab activities and experiments.

The supervisors of elementary schools, principals, honors workshop participants, and team leaders must also monitor the program and teachers' performance to ensure that omissions or modifications to the program are not occurring to the point that they are undermining or conflicting with its intent and purpose. Collaboration with fellow teachers to produce better student outcomes is welcomed.

Teachers who are successful with the program are motivated to teach it because of the excitement and enthusiasm of their students. Teachers using the program as intended and teaching it properly are more inclined to derive success with their students. Students currently in the program frequently cite science as their favorite subject, even ahead of lunch and recess.

An area requiring further refinement involves changing teacher attitudes and notions regarding student evaluation and grading. Teachers still tend to seek objective data with which to grade students and are inclined to feel a need for more objective, content-oriented tests rather than observing whether the student appears to understand and utilize the scientific processes in his/her classroom performance and experiences. Concerns expressed in this area appear to be far fewer than initially as teachers begin to truly understand and feel comfortable with the philosophical and educational premise of the program.

CONCLUSION

The Carroll County elementary science program has been an extremely successful curriculum characterized by a high degree of teacher support and student motivation. Student learning is predicated upon hands-on experiences which emphasize the processes of science. Youngsters undertake a planned sequence of activities in both the biological and physical sciences directed toward the development of problem solving skills. Research data to date give added evidence of the success of this program.